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Characteristics of NWC VLF Signal at 22.3 kHz propagated over a Distance of 5.7 Mm

Barin Kumar De

Department of Physics, Tripura University,
Agartala 799 004, Tripura, India

S. K. Sarkar

Department of Physics, Calcutta University,
92 APC Road, Calcutta 700 009, India

Abstract : The NWC VLF signal at 22.3 kHz transmitted from North West Cape, Australia is being studied at Calcutta. The great circle distance is 5.7 Mm and it is an S-N propagation over sea. The signal exhibits remarkable transition at sunrise from higher nighttime value to lower daytime value. The night-to-day variation exhibits a seasonal characteristics. At times when propagation path is partially illuminated, a single waveguide mode incident on the discontinuity between night and day portion of the path, can result in the generation of several modes. The modal conversion and then interference between higher order modes are causes of sunrise fade. The nighttime signal is reflected from 90 km and the daytime signal from 70 km. The drift of conductivity parameter from nighttime value to daytime value is the reason for night-to-day variation.

Keywords : VLF signal, ionosphere

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1. Introduction

The D-region of the ionosphere extending from 60 to 90 km is the result of photo-ionization of atmospheric nitric oxide (NO) by solar Lyman-α radiation. The electron density of this region is very sensitive to solar radiations. The important feature of this region is that it disappears at night. Very low frequency (VLF) radio wave reflected from this region is influenced by both concentration and collision frequency of electrons. Studies of VLF propagation at different frequencies have been made from time to time [1,2,3,4]. But the study of VLF signal along transequatorial path over sea is scanty. We are in a privileged position at Calcutta with respect to propagation of 22.3 kHz from North West Cape, Australia. Here we are communicating a short report on the behaviour of 22.3 kHz NWC signal.

2. Experiment

Transmitter: The 22.3 kHz radio wave, call sign NWC, is transmitted continuously from North West Cape, Australia at power of radiation of 1 MW.

Receiver: The amplitude is being recorded after amplification of emf induced in a tuned loop aerial. The diagram of the receiver is shown in Fig.1. The AC amplifier has been designed using high slew rate OP AMP 531 whereas the DC amplifier is of OP AMP 741. The maximum gain of the receiver is 100 dB with overall bandwidth of 200 Hz. The recording chart speed is 2 cm/hr with time constant of 7.5 s.

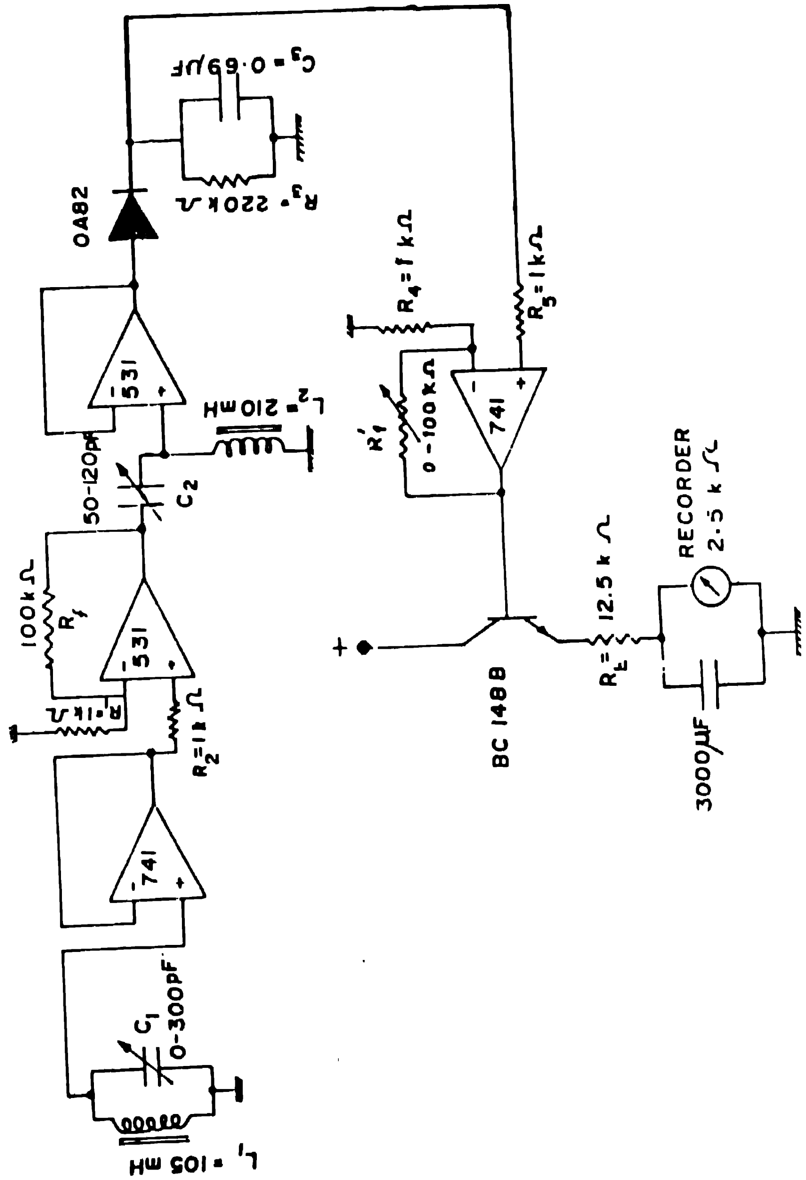

Fig.1. Diagram of the receiver to record the VLF signal amplitude at 22.3 kHz.

Propagation path : The location of transmitter (T) and receiver (R) are shown in Fig.2. The great circle distance between North West Cape (22°49′S,114°E) and Calcutta is (22°34′N,88°24′E) is 5,7Mm. The main features of the path are that it is a transequatorial path over completely over sea, and transmitter and receiver are symmetrically situated with respect to magnetic equator, Considering normal electron density profile, the daytime and nighttime reflecting height are 70 and 90 km. respectively.

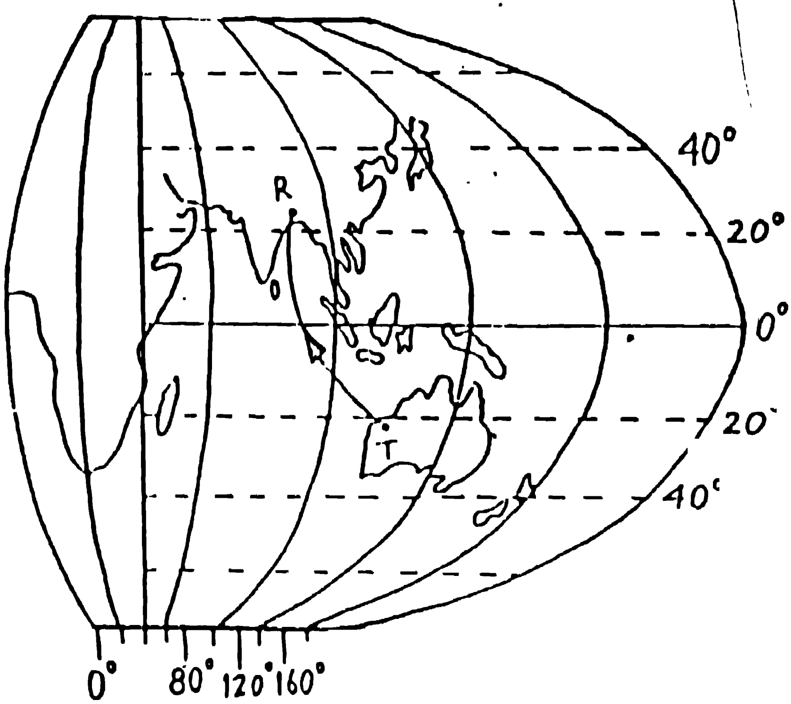

Fig.2. Map showing the geographic locations of transmitter (T) at North West Cape, Australia and receiver (R) at Calcutta, India.

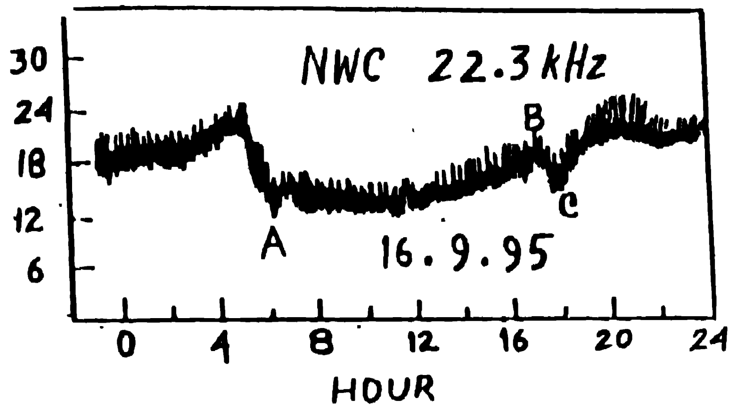

Fig.3. Typical record of 22.3 kHz NWC signal. The amplitude is in terms of induced voltage at the antenna in dB above 1 μV. Time is in IST. A:morning minimum, B: afternoon maximum and C:sunset minimum.

3. Observations and results

Typical record of signal exhibiting diurnal variation is shown in Fig.3. The main feature is that average nighttime level is higher than average daytime level. The signal exhibits remarkable decrease during sunrise transition. As the sunrise occurs at the ionospheric reflection zones, the amplitude gradually fade out showing a 'minimum' known as 'morning minimum' (A). The signal level remains low up to midday. After that the signal level gradually increases showing a 'maximum' (B). After sunset at the ionosphere, the signal exhibits a small fade (C) which is followed by a gradual rise to the nighttime value. Depth of sunrise fade on the days near the middle of each month are shown in Table 1.

Table I
Depth of sunrise fade and sunset fade observed in the middle days of each month.

Dates	*Av. nigthtime level in db above 1µV*	*Depth of sunrise fade (db)*	*Depth of sunset fade (db)*
15.06.95	22	12	6
16.07.95	20	9	4.5
14.08.95	19	7	4
16.09.95	21	8	1.5
14.10.95	25.5	14	6.5
17.11.95	27	14.5	7
15.12.95	23.5	11	5
16.01.96	20.5	8	4.4
13.02.96	19	7	4
15.03.96	23	9	5
18.04.96	25	13	6
16.05.96	26.5	13.5	7

4. Discussion

The propagation of radio wave over large distance is treated as waveguide mode propagation. The surface of the earth is the lower boundary and D-region of the ionosphere is the upper boundary of waveguide. For jth mode of propagation the electric field is given by [5]

$$E_j \propto |Z| \; exp(-a_j d) \; exp[i\omega t-(d/v)+ Arg \; Z_j] \qquad (1)$$

where Z = excitation factor of Jth mode, a_j = attenuation rate of jth mode, v = phase velocity and d = transmitter to receiver distance. The lower surface of the E-region at night and D-region at day play the role of upper surface of earth-ionosphere waveguide, Over this large distance only the first mode [5,6] is dominant. The attenuation rate of the first mode is dependent on conductivity parameter ω_r given by $\omega_r=\omega_0^2/\nu$ where ω_0 is the angular plasma frequency and ν the collision frequency. Due to lower value of ν and higher value of ω_0, conductivity parameter is much higher at E-region compared to that in D-region. As a result, the signal is less attenuated at night than at day. This explains higher nighttime level in all months.

At the times when a propagation path is partially illuminated as at sunrise and sunset transitions, a single waveguide mode incident at discontinuity between night and day portions of the path can result in generation of several modes of propagation away from the discontinuity. This is referred to as mode conversion[7]. The interference between the modal components produces amplitude perturbation. Sunrise effect and sunset effect are the manifestations of such modal interference. The magnitude of sunrise fade and sunset fade are dependent on the variation of ω_0 experienced by VLF signal as the upper reflecting surface is drifted from lower E-region to D-region after sunrise, and D-region to E-region after sunset.

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